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A Dressing System Providing Fluid Supply and Suction Drainage Used for Continuous or Intermittent Irrigation

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In this article a dressing system is described that is capable of providing continuous or intermittent wound irrigation. It is based on a felt dressing provided with an adhesive cover and ports for fluid supply and suction drainage. At continuous irrigation (approximate rate, 70 ml/h), a 1-L fluid bag and a siphon about 30 cm in height are used; at intermittent irrigation (approximate rate, 60 ml/min), a 60-ml fluid bag and a suction balloon are used. In an experimental set-up it was shown that the supplied fluid diffused throughout the dressing felt and that the felt was partly saturated both during continuous and after intermittent irrigation, the effect of gravity being counteracted by capillary force and suction. The suction pressure at the drainage port and within the occlusively applied felt showed a linear relationship. The drainage of particles, while relatively impeded at low flow rates, was satisfactory at rates recommended for clinical use. The dressing felt was inert to adherence of bacteria and white blood cells. This dressing system would seem to provide access to the whole wound surface for active therapy through fluid supply and suction drainage.

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A porous dressing with supply and drainage ports permitting continuous or intermittent irrigation of a bandaged wound has been reported [11]. Continuous saline irrigation has been used for the rapid cleansing of leg ulcers [12]; used postoperatively for intractable leg ulcers with meshed split-skin grafts, it has been found to promote graft take [1]. Intermittent irrigation has been found to be a practical way of cleansing leg ulcers [13]. In such applications wound drainage has proved so efficient that the interval between dressing changes could be prolonged. The irrigations are done in the following way: The dressing (Fig 1) consists of a sheet of polyester rayon felt with ports for supply and drainage and a soft, pliable cover of water-impermeable polyurethane coated with an adhesive. The cover, framing the felt, allows occlusive application to the skin after the felt has been cut to fit the wound. The dressing is kept in place by a gauze pad and bandages. Its pliability allows it to adjust itself readily to uneven surfaces. During continuous irrigation, fluid is supplied by an intravenous drip set (fluid bag positioned not higher than 0.5 m above the supply port, delivery rate 20 to 30 drops/min). Suction drainage is usually provided by a siphon connected to an elastic balloon and a fluid collection bag, suction being initiated mechanically by compressing the balloon. Suction by pump is used only when the wound cannot be satisfactorily sealed. Treatment is interrupted for periods of ambulation. During intermittent irrigation, a pliable bag containing 60 ml fluid is connected directly to the supply port and a suction balloon with a collection bag to the drainage port (see Fig 1). Once the balloon has been compressed, the fluid is sucked out through the drainage port within about one minute. The procedure is usually repeated 3 times daily. In this study we assessed the fluid diffusion within, and the removal of particles from the felt, as well as the felt fluid saturation, pressure, and flow. The adherence of biological particles to the material was studied, as was the transport of bacteria through the dressing.

Material and Methods

The experimental dressing had a felt volume of 13 × 8 × 0.3 cm (pore volume, 65%); the ports were 10 cm apart from each other. The set-up used for the in vitro testing is shown in Figure 2. The dressing was glued by its cover to a rigid transparent plate. Tests were made on dressings both without air access and with an air inlet (3 mm in diameter) located 1 cm from the

drainage port (corresponding to the clinical situation when the dressing cannot be satisfactorily sealed) under conditions of continuous or intermittent irrigation with isotonic saline unless otherwise indicated. A roller pump was used to supply fluid at rates of 55 or 180 ml/h while another pump, the described siphon system or the balloon, was used for suction (pressure, −300 mm H_2O unless otherwise indicated).

The diffusion of fluid throughout the felt was examined by following the spread of nonparticulate ink during its passage from port to port, and the removal of particulate matter from the felt was studied by observing the removal of India ink particles (2 μm in diameter). Both processes were studied in dressings with no air inlet and recorded photographically.

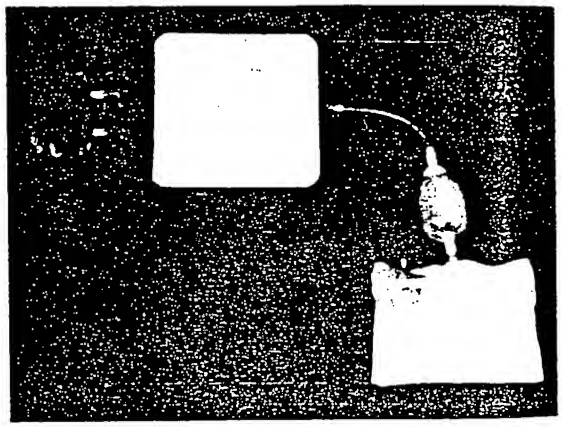
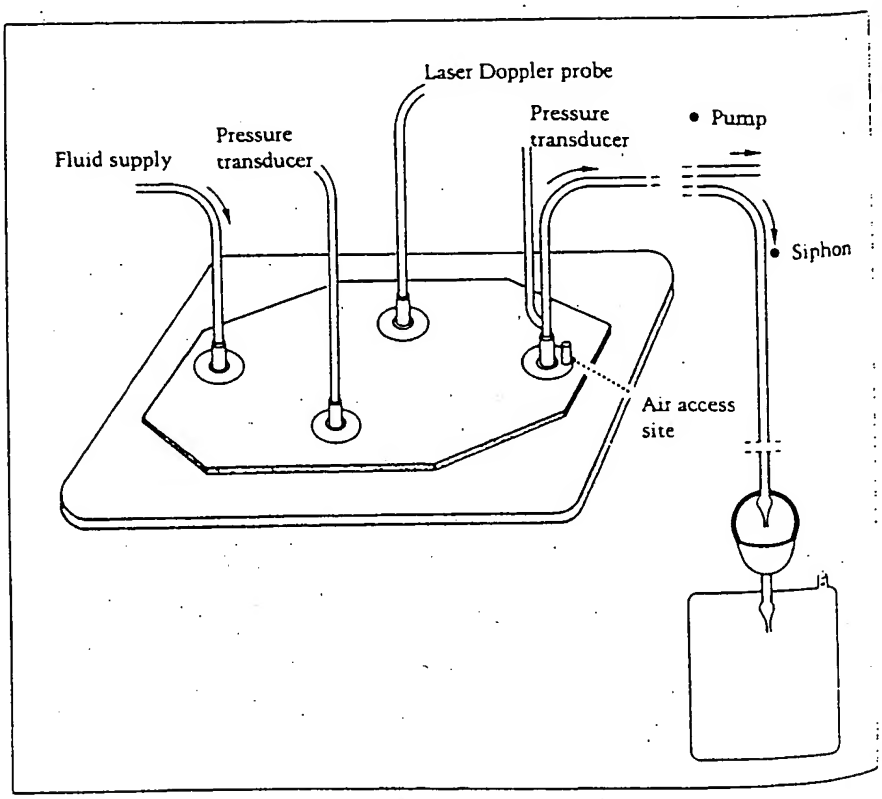


Fig 1. Dressing with pliable bag for fluid supply, elastic balloon, and collection bag, as used for the intermittent irrigation of a wound.

Fig 2. Experimental set-up.



Fluid saturation of the felt, assessed by weight, was measured after irrigation had first been allowed to proceed for 30 minutes, with the dressing positioned horizontally or vertically with the drainage ports at the upper or lower end. The rate of fluid supply was varied in one set of experiments. Fluid saturation was also measured after intermittent irrigation with the dressing in the horizontal position. The values were expressed as percentages of the total saturable volume.

Flow within the felt was assessed with a laser Doppler flow meter (Perimed, Sweden) during continuous irrigation with a Latex particle suspension (0.2 μm in diameter, 1.04 g/cm^3 density, 4.4 g/dl concentration). Dressings were horizontally positioned, with the light-emitting probe immobilized on the cover at a point equidistant from the ports. The output signal was related to the quantity and speed of the particles within the felt beneath the probe [9]. Various rates of fluid supply were tested. The measurements were recorded graphically in volts.

The pressure in the drainage port and within the enveloped felt in a volume equidistant from the ports was measured continuously (EMT 746 pressure transducer, Siemens-Elema, Sweden; connected to an electronic pressure amplifier) during irrigation of the dressings horizontally positioned. Suction pressure at the drainage port was varied both by means of a pump and by compressing the elastic balloon on the siphon. All measurements were recorded graphically in mm H_2O.

The adherence of bacteria and white blood cells to the felt was assessed as follows. Through each of 2 vertically positioned Pasteur pipettes, their bores packed with 70 mg felt to a volume of 0.3 cm^3, was run 1 ml solution of *Staphylococcus aureus* or *Escherichia coli* in isotonic saline (concentration 10^{5-8} colony-forming units [CFU]/ml) followed by 1 ml saline; 10 experiments were made with each type of bacteria. The number of CFUs was assessed before and after the passage, adherence being expressed in percentages of the concentration before passage. Through 3 similarly prepared pipettes, 1 ml heparinized blood was run; 6 experiments were done with blood from each of 5 donors. The total number of white blood cells and polymorphonuclear leukocytes per milliliter blood was assessed before and after passage, and adherence was expressed in percentages.

Transport of bacteria through the dressing was tested by applying the dressing to the surface of agar plates densely cultured with *S. aureus*, *S. epidermidis*, *E. coli*, or *Pseudomonas aeruginosa* and irrigating continuously with isotonic saline for 24 hours. Two experiments were made with each type of bacteria, samples of drainage fluid being taken at intervals and conventional saline dressings serving as controls. After the removal of dressings, the plates were incubated for 48 hours and checked for bacterial growth. The number of CFUs per milliliter drainage fluid was assessed.

Results

During both continuous and intermittent irrigation, ink diffused to the outermost parts of the felt (Figs 3A, 4A). Channels allowing preferential passage of the fluid were not observed. India ink particles were eliminated during 18 minutes of continuous (Fig 3B), and during 16 seconds of intermittent irrigation (Fig 4B).

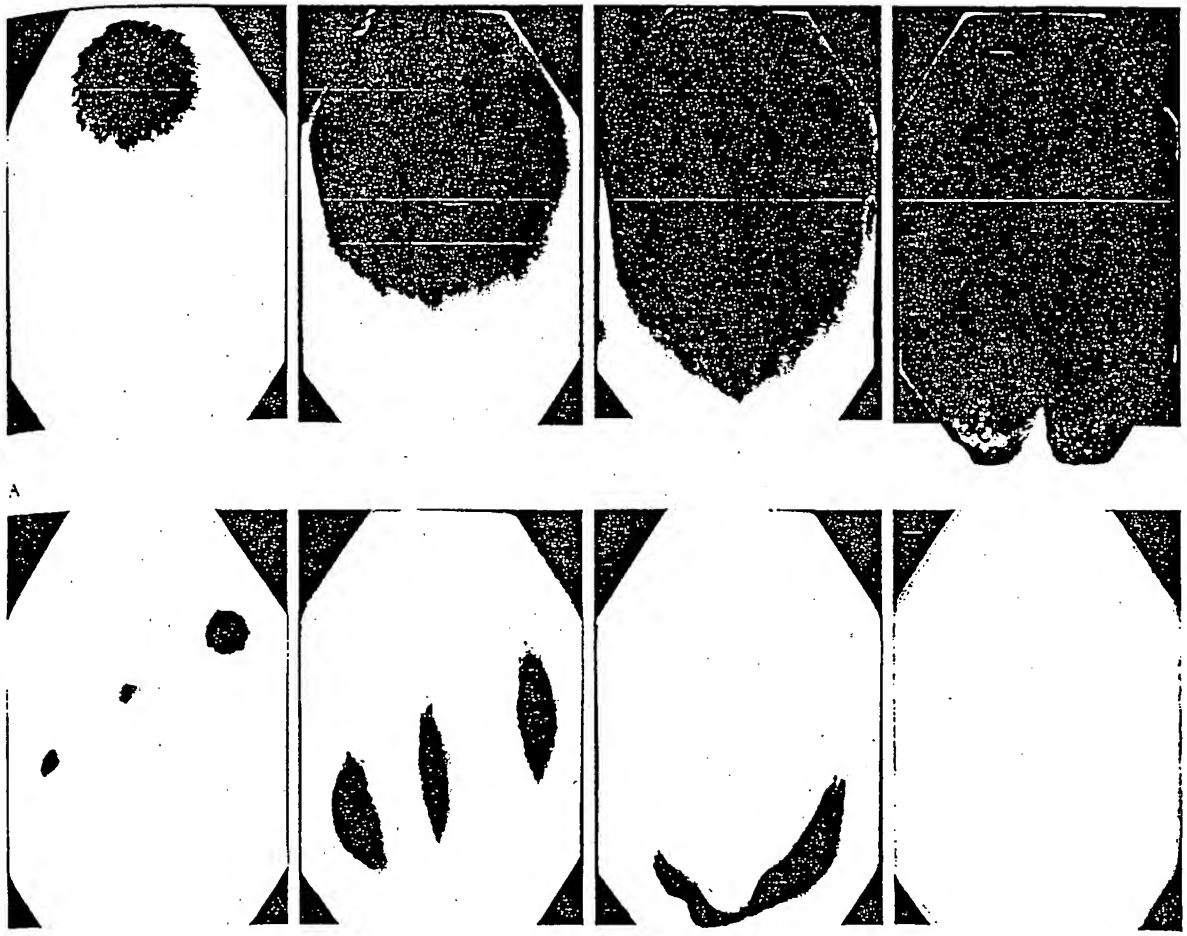
Mean values for fluid saturation of the felt during continuous irrigation (Table) ranged from 64% to 85% for dressings without air inlets in their covers and from 50% to 81% for dressings with air inlets. The upper range values were those from dressings with the drainage port at the upper end and the lower range from those with the port at the lower end. In separate experiments we have shown that, at a supply rate of 55 ml/h, the felt becomes saturated with fluid only when the suction pressure is greater than -100 mm H_2O. After intermittent irrigation, mean fluid saturation was 49% (range, 40 to 52%).

At low rates of fluid supply, relative increases in laser Doppler values were observed (Fig 5). The flow pattern in dressings both with and without air inlets was pulsatile.

The pressures at the drainage port and within the felt were linearly related ($r = 0.98$) as assessed in 5 experiments on dressings without air inlets; a typical recording is shown in Figure 6A. With air inlets, the pressure in the felt approached atmospheric pressure and was never less than -100 mm H_2O, even at drainage port pressures of -400 mm H_2O; a recording is shown in Figure 6B. The pressure at activation of the siphon suction system was -700 mm H_2O. The time course of the pressure curve is shown in Figure 7. The adherence of *S. aureus* to the felt was 19 ± 3% (mean ± SE) and of *E. coli* 14 ± 3%. The adherence of total white blood cells was 7.5 ± 3% and of polymorphonuclear cells 17 ± 4%.

There was no bacterial growth on agar plates irrigated for 6 hours, whereas all controls showed growth. The bacterial concentration in the drainage fluid increased during the first 60 to 90 minutes of

Fig 3. (A) Diffusion of nonparticulate ink during continuous irrigation; photograph on far right taken 18 minutes after injection. (B) Transport of India ink particles during continuous irrigation; photograph on far right taken 18 minutes after injection. Dressing positioned at 45 degrees to the horizontal with the inlet port at the upper end.



A

B

Fig 4. (A) Diffusion of nonparticulate ink during intermittent irrigation; photograph on far right taken 16 seconds after injection. (B) Transport of India ink particles during intermittent irrigation; photograph on far right taken 16 seconds after injection. Dressing positioned at 45 degrees to the horizontal with the inlet port at the upper end.

Fluid Saturation of Felt (%) During Continuous Irrigation

Dressing Cover	Fluid Supply Rate (ml/h)	Dressing*		
		Horizontal	Vertical; Drainage Port at Lower End	Vertical; Drainage Port at Upper End
Without air inlet	55	81 (78–84)	64 (62–66)	85 (81–91)
With air inlet	55	58 (57–61)	50 (42–53)	77 (76–77)
With air inlet	180	66 (65–68)	56 (55–57)	81 (79–84)

*Four dressings were used. Each value is based on at least 4 measurements. Values are mean (range).

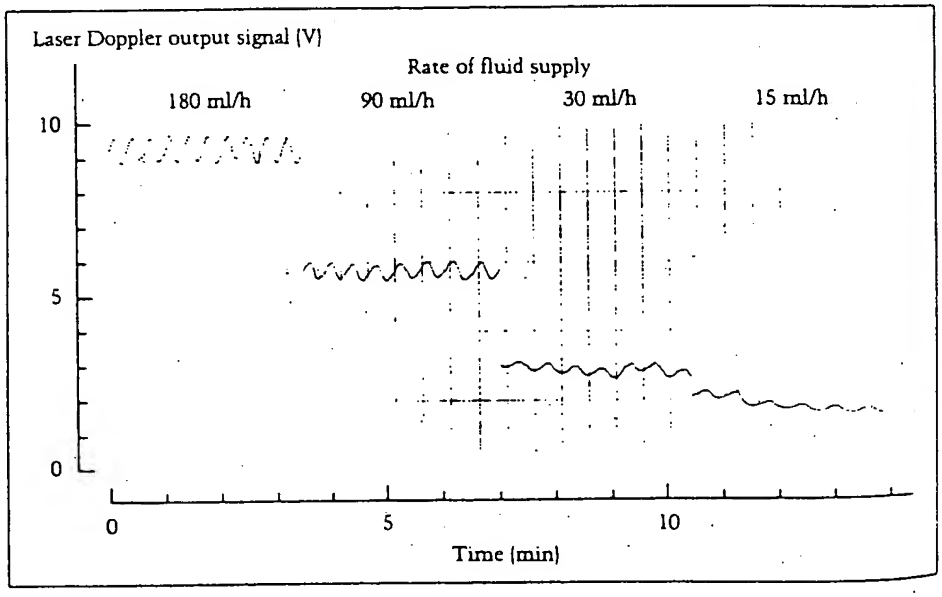


Fig 5. Flow of Latex particle suspension within the dressing felt at different supply rates. Dressing with air inlet.

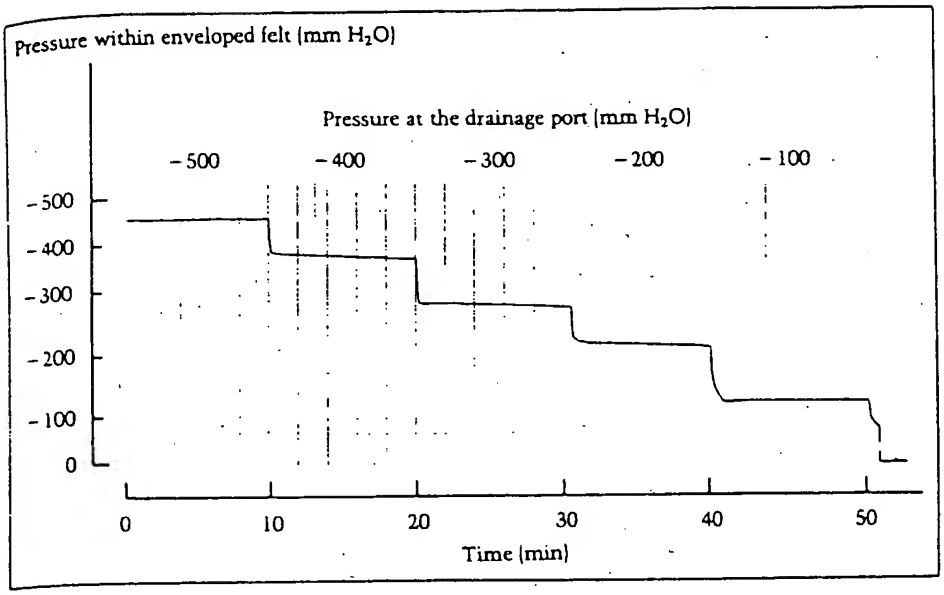
irrigation and then rapidly decreased. The peak mean value was $385 \times 10^8 \pm 195 \times 10^8$ CFU/ml. At 4 hours the value was $28 \times 10^8 \pm 1 \times 10^8$, at 6 hours $17 \times 10^8 \pm 3 \times 10^8$, and at 24 hours less than 3×10^8.

Discussion

The irrigation techniques for continuous wound treatment, originally reported by Carrel and Dehelly [2], are practically applied only to selected patients with surgical or orthopedic infections [6, 10]. We describe a dressing system that can be used on different types of wounds, directing treatment to the wound surface either continuously or intermittently by means of fluid supply and suction drainage.

The dressing felt offers a resistance to flow that is overcome by the positive pressure applied at the supply port (hydrostatically or by pump) and the negative pressure or suction at the drainage port (by siphon, suction balloon, or pump). Build-up of a positive pressure within the dressing, which might strain its seal, is avoided by applying fluid supply and suction drainage jointly and by keeping the hydrostatic pressure low. Indeed, at continuous irrigation with an occlusively applied dressing the hydrostatic pressure may be reduced to zero, siphon suction alone overcoming the resistance of the system.

During both continuous and intermittent irrigation, diffusion occurred throughout the felt, indicating that the treatment fluid would act on the total underlying wound surface. The distribution and passage of fluid in the felt are guided by the capillary force with an added element of negative pressure within dressings that are occlusively applied. In these,



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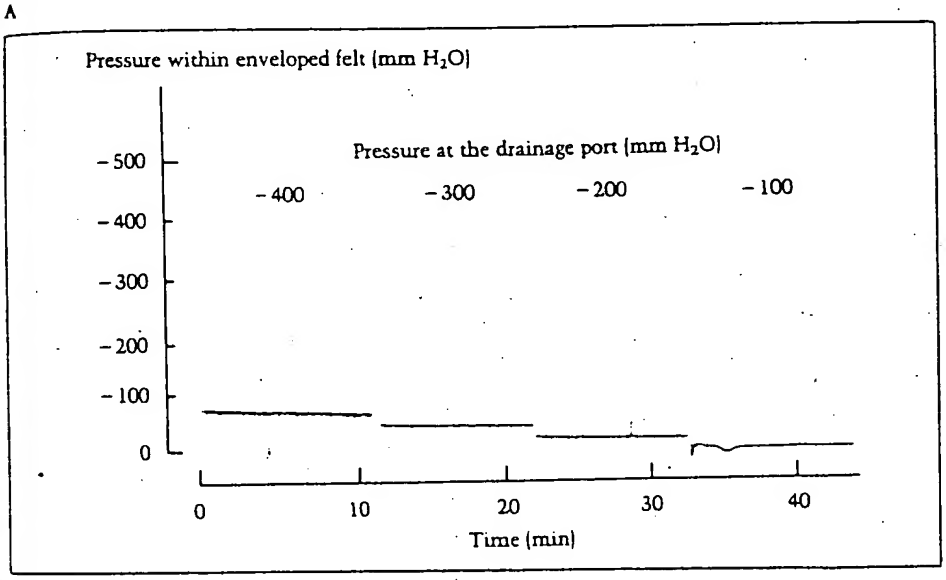

B

Fig 6. (A) Pressure within a dressing and in its drainage port during continuous irrigation (rate 55 ml/h). Dressing with no air inlet. (B) Pressure within a dressing and in its drainage port during continuous irrigation (rate 55 ml/h). Dressing with air inlet.

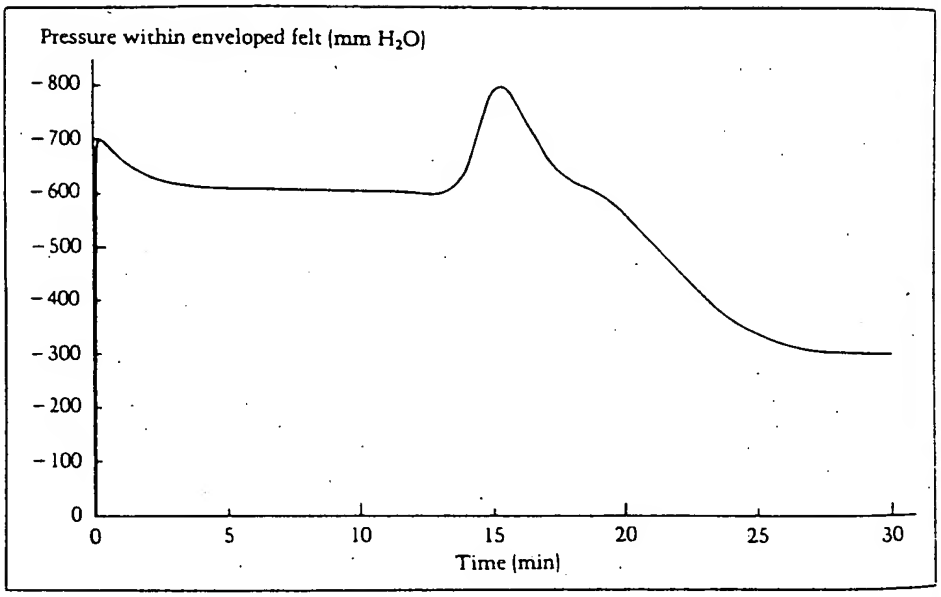

Fig 7. Pressure within a dressing during continuous irrigation (rate 55 ml/h) at activation of siphon suction. Dressing with no air inlet.

the pressure may be adjusted under control simply by changing the height of the siphon. During continuous irrigation the discovery that the felt is partially saturated, even when the drainage port is positioned at the upper end of a dressing with an air inlet, indicates that the effect of gravity is counteracted by the capillary force and suggests that the felt may function as a wick. However, dependent drainage is seen to decrease the degree of fluid saturation, a finding that may be used clinically [12].

The efficiency of the continuously applied drainage is indicated by the findings that the supply rate to and the transit rate through the dressing may be varied within a wide range without affecting the degree of fluid saturation in the felt (see Table). The particles of India ink or bacteria that are taken up into the felt are sucked out with the fluid to the drainage port, a process facilitated by the inertness of the felt. However, the presence of bacteria in the drainage fluid also at 24 hours shows that some adhesion does occur. The relative increases in the laser Doppler values at a supply rate as low as 15 to 30 ml/h (see Fig 5) indicate the presence of an increased number of particles within the measuring volume and suggest that drainage efficiency is enhanced when the fluid transit rate is increased to levels recommended for clinical use.

In the intermittent irrigation technique fluid is distributed more rapidly and particles are eliminated more quickly than during continuous irrigation. The negative pressure, increased well above that used during continuous irrigation, improves the drainage efficiency. Between irrigations an effect may still be exerted by treatment fluid remaining in the felt, and fluid, i.e., exudate, may be taken up into the open pores.

The appropriateness of applying this dressing system to open wounds is based on the obvious importance of the local environment to healing. Moisture has been shown to enhance epithelialization [7, 15] and keratinocyte cultures grow at rapid rates given certain culture conditions [3]. The rate and quality of healing is related to topical oxygen supply [5] and to local nutrition [8, 14]. Drained infected wounds are cleansed and heal faster than controls [4]. The dressing would seem to allow access to the whole wound surface for active therapy; fluid and medication may be supplied, moisture retained, and drainage ensured. Treatment may be given continuously or intermittently according to clinical requirements.

References

1. Arnljots B, Svedman P: Irrigation treatment in the split thickness skin grafting of intractable leg ulcers. Scand J Plast Reconstr Surg 19:211, 1985
2. Carrel A, Dehelly G: The Treatment of Infected Wounds. New York, Paul B. Hoeber, 1919
3. Green H, Kehinde O, Thomas I: Growth of cultured hu-

man epidermal cells into multiple epithelia suitable for grafting. Proc Natl Acad Sci USA 76:5665, 1979
4. Groenewald IH: An evaluation of dextranomer as a cleansing agent in the treatment of the post-phlebitic stasis ulcer. S Afr Med J 57: 809, 1980
5. Kaufman T, Alexander JW, MacMillan BG: Topical oxygen and burn wound healing: a review. Burns 9:169, 1984
6. Kawashima M, Tamura H: Topical therapy in orthopedic infection. Orthopedics 7:1592, 1984
7. Miller TA, White WL: Healing of second degree burns. Plast Reconstr Surg 49:552, 1972
8. Niinikoski J, Kivisaari J, Viljanto J: Local hyperalimentation of experimental granulation tissue. Acta Chir Scand 143:201, 1977
9. Nilsson GE, Tenland T, Öberg PÅ: Evaluation of a laser Doppler flowmeter for measurement of tissue blood flow. IEEE Trans Biomed Eng BME-27, 10:597, 1980
10. Smith-Petersen MN, Larson CB, Cochran W: Local chemotherapy with primary closure of septic wounds by means of drainage and irrigation cannulae. J Bone Joint Surg 27:562, 1945
11. Svedman P: A dressing allowing continuous treatment of a biosurface. IRCS Med Sci 7:221, 1979
12. Svedman P: Irrigation treatment of leg ulcers. Lancet 1:532, 1983
13. Svedman P, Sandén G, Banck G: Treatment of leg ulcers by intermittent irrigation through a felt dressing. IRCS Med Sci 13:489, 1985
14. Viljanto J, Raekallio J: Local hyperalimentation of open wounds. Br J Surg 63:427, 1976
15. Winter G: Formation of the scab and the rate of epithelialization of superficial wounds in the skin of the young domestic pig. Nature 193:293, 1962